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The influence of the construction methods on the design

Influence des méthodes d'execution sur la conception

Einfluss der Ausführungsmethoden auf den Entwurf

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SUMMARY
The important nuclear power plant programme, under construction in France is performed out of execution drawings which, in theory, must not be modified. New construction methods and especially heavy prefabrication methods—which would enable to save time and money—will probably make the nuclear power plant civil engineering design progress and improve its adaptation to new methods.

RESUME
L'important programme de centrales nucléaires en cours de construction en France, s'exécute à partir de plans d'exécution qui, en principe, ne doivent pas être modifiés. De nouvelles méthodes de construction et notamment l'utilisation de méthodes de préfabrication lourde—qui peuvent apporter des économies d'argent et de délai—permettront sans doute de faire évoluer la conception du génie civil des centrales nucléaires et de l'adapter mieux à ces nouvelles méthodes.

ZUSAMMENFASSUNG
Das zur Zeit in Frankreich im Bau befindliche bedeutende Atomkraftwerkbauprogramm basiert auf Ausführungsplänen, die grundsätzlich keiner Modifizierung bedürfen. Neue Ausführungsmethoden jedoch, und speziell die Anwendung neuer Vorfabrikationsmethoden für schwere Bauteile, die Zeit und Geld sparen, werden es in Zukunft erlauben, Fortschritte im Atomkraftwerk-Ingenieurwesen zu machen.

The aim of this paper is to illustrate how prior choice of construction methods can influence and inflect design.

In France, any such possibility arises solely when the Client puts out an open, competitive call for tenders. In this case, only the bare outlines of the project are laid down by the Client and the Contractor is free - within the set limits- to design and implement the project using the means and methods specific to his company or any others which he may deem suitable.

However, the most frequent case is the call for tenders in respect of a precisely defined project.

The methods by which the contract will be carried out flow from the design without being able to influence it and, if one wishes to use new methods it is necessary to study an alternative, different project which is not always permitted.

It is from the standpoint of the latter case, the most frequent, that I will try to demonstrate that, even when the project is defined very precisely, it is, sometimes, possible to cause it to evolve in line with the construction methods and which differ from those which would normally be applied.

By way of illustration I would like to address nuclear plant civil engineering.

For a number of years now, the French nuclear programme has been one of the main activities of civil engineering in France.

The building of nuclear plants is carried out on the basis of drawings supplied by E.D.F., the French Central Electricity Board, to the Contractor.

These drawings are made by E.D.F. with the aid of outside Consulting Engineers. They remain the same for all plants of the same type, apart from the adaptation -to-site-drawings- which may vary from one site to another, depending on the varying ground conditions.

E.D.F. alone is entitled to make any changes, which usually are minor ones and are normally due to developments in the electromechanical field. The Contractor may not make any changes.

Within the framework of the CP1 programme - which comprises twenty tranches of 900 MW - E.D.F. has contracted our company to construct 4 of those tranches. 2 at Saint-Laurent-des Eaux, and 2 at Chinon. The equipment and working methods which we planned and introduced on the sites did not differ greatly from those used by other companies for the same type of plant on other sites.

Very soon we reached the conclusion that it would perhaps be advantageous to use prefabrication methods - already in use in the building trade - adapting and developing them to our needs, even although the design and implementation methods had not been worked out with prefabrication in mind.

Why use prefabrication ?

Generally speaking prefabrication is envisaged when a number of criteria exist, the two main ones being :

- Repetition : a large number of identical or similar components have to be built.
- Complexity : a number of complicated framework systems, or high-rising framework systems have to be built and which require costly shoring which one would like to simplify or even do away with altogether.

The repetition criterion is not met in the case of nuclear plant civil engineering ; on the other hand, it most certainly meets the complexity one.

What advantages may we expect ?

Prefabrication offers :

- a reduction in the total number of hours to be worked, (time gain)
- quality improvement
- safety improvement.

Time Gain :

Time savings result from the improvement in unit production which one can hope to achieve on those activities amenable to prefabrication, i.e.
. reinforcement,
. frameworking and shoring,
. concreting.

Prefabrication also enables a certain amount of work to be done off-site, or even to be sub-contracted to an outside firm thus reducing the number of workers on the site. This leads to better to relations on the labour front on the site, improved use of manpower and, at the end of the day, improved overall production.

The savings made on time may be used in two ways :

- By shortening the construction time of the plant or part of the plant. That, however, is only advantageous if the plant of the part concerned is on the critical path and if the follow-up work is not behind schedule.

- By smoothing out the site-workers curve. In the case of a nuclear plant site, the curve representing the number of workers as a function of time is a rather sharp one. It tends to flatten out over a relatively short period, of about one year (for a site with two tranches) and which corresponds to the number of workers required, once cruising speed has been attained. This number should be as low as possible. The reason for this is that it is only possible to increase this number by bringing in people from far away - which costs a lot of money - since local labour sources have been used up.

It would also mean setting up reception centres and additional housing facilities (accommodation, cantines, changing-rooms) which could not be amortized over the time during which they would be required.

Quality improvement :

Prefabrication enables a considerable amount of work to be carried out at ground level and not up in the air. It makes for easier working, less difficult supervision and planning. The work is more accurate, therefore of better quality.

Improvement in safety :

Prefabrication enables avoidance of a great deal of work at heights or in difficult access conditions, thus reducing accident risk and in particular, serious

falls.

We tried to implement the fore-going ideas on the Saint-Laurent-des Eaux site, then on the Chinon site despite the constraints already referred to, namely :

- Total ban on modification to the plans,
- Equipment and working methods not adapted to prefabrication methods : handling equipment in particular ; traditional equipment for traditional type work. Mainly tower cranes which did not exceed 300 t/m. The weight of loads at the end of the jib could not exceed 7 tonnes, which is very insufficient for concrete prefabricated components.

At Saint-Laurent-des Eaux and at Chinon we therefore limited ourselves to reinforcement trussings and floor units.

Reinforcement trussings were used to produce a great number of units or frames for bedding, slabs, beams and floors of almost all of the buildings. By using weldable reinforcing rods we were able to assemble highly rigid panels or frames which did not deform on handling or when the concrete was poured. At the same time we were able to improve on the quality of trussing.

Taking advantage of the temporary presence of a high-power crane on the Chinon site, we were able to put into position at one go a trussing unit weighing more than 25 tonnes.

Pre-cast concrete slabs :

These were used for the first time when we were constructing the plant's water supply galleries. The conventional method is to pour the roofing slab in situ which entails having a very complicated shoring system bearing on the BONNA pipe. Produced in the form of a self-supporting pre-cast slab, the work involved took very little time and did not require much labour.

Using the pre-cast concrete slab system we were also able to produce a considerable number of the floors for the various buildings, in particular for the machine room and the power installations which normally require high-rising shorings which we were able to cut down on or eliminate altogether.

At the same time, we pursued our prefabrication studies with a view to breaking out of the straight-jacket-like limitations imposed on us at Saint-Laurent-des Eaux and Chinon. Our studies proved that it is possible to envisage two types of prefabrication :

1) - medium-weight prefabricated units with a maximum weight of approximately 50 tonnes : this concerns :

1.1 - prefabrication of trussings - limits being imposed not by weight but by overall dimensions of units.

1.2 - prefabrication of mainly self-supporting pre-cast slabs of large cross-section which eliminates any shoring work.

1.3 - prefabrication of beams, joists or ribs

1.4 - possibly, the prefabrication of finished floor components.

1.5 - prefabrication of non-structural slab components, the weight of which is not too great due to their small size.

1.6 - restoring of continuity between concrete components by using reinforcing rods and not costly special tie systems.

1.7 - use of non-job-specific hoisting apparatus which can be re-used on sites other than nuclear plant sites and which can therefore be more readily amortized - such as American Hoist 9310 or Manitowoc 4100.

2) - heavy-weight prefabricated units up to 250 tonnes and which comprise prefabricated components of all types, including structural slabs, but which require :

- special heavy handling equipment,
- costly special ties between prefabricated components.

The outcome of these studies and their application at Saint-Laurent-des-Eaux and Chinon, although limited, seemed to be promising enough to E.D.F.that they authorized us to run a medium-weight prefabricated unit trial (units up to 50 t) on the 2 x 1,300 MW tranches on the Belleville site, the contract for which we have just been awarded within the context of the twenty tranches programme involving a number of sites.

As was the case in the 900 MW tranches, the working drawings for the 1,300 MW are valid for all the plants of the same type. However they already take partly into account the possibilities of prefabrication techniques developed and adopted for the afore-mentioned sites.

Moreover, by anticipating long enough in advance the start-up of the work, the time necessary for re-thinking the plans which did not take prefabrication into account was able to be found without affecting the stipulated construction time.

There remains however, a certain number of limitations which restrict the full utilisation of the outcome of the experiment :

- We are still prohibited from changing the overall dimensions of the construction, hence of the framework plans. We may modify only the trussing plans.

- The cost of the trussing plans is borne by the company. For each plant, or part of a plant, it is necessary to callate the cost of re-doing the plans with the savings hoped for from prefabrication. This leads to rejecting prefabrication - which might be advantageous from a technical point of view - but which entails costly adaptation of the plans.

The experiment on the Belleville site will require adapting approximately 700 trussing drawings.

The conventional equipment using tower cranes, complemented by a Manitowoc 4100 with a Ringer 2000 t/m. Prefabrication will involve :

- virtually all of the trussing work,
- floors of the main buildings (Nuclear Ancillary Equipment, Fuel Buildings, Reactor Building),
- beams and floors (pre-cast slabs) for the machine room,
- possibly some of the non-structural slab units.

For the two tranches concerned we reckon that the total number of units which will have to be handled will be approximately 1000, i.e. a little more than one unit per day. A figure which is insufficient to permit of full utilisation of the Manitowoc. Additionally, it could also be used for lifting or positioning metal components or heavy electromechanical equipment which normally means

bringing in equipment from outside as required, the transport of which, to and from the site being extremely costly.

Conclusion :

From the afore-going - based on an on-going experiment - it can be seen that even in the case of a set project it is possible to use alternative, different means and working methods which, little by little, bring about changes in design. The example of the nuclear plants has, of course, advantages and disadvantages.

Positive aspects : Series construction spread over a number of years thus offering a time advantage to allow the design to evolve in line with new working methods.

Negative aspects : Civil engineering is tied to the available electromechanical equipment and which, because of long leads involved, is ordered well in advance. In the short term, therefore, structural changes are practically impossible. It is for this reason that prefabrication of reinforcements and the use of precast concrete slabs is now included in the various stage plans of the 1,300 MW plant as a result of the trials in Chinon and Saint-Laurent-des-Eaux. It is quite possible that the medium-weight prefabrication experiment being carried out at the Belleville site will have a certain spin-off on other sites and that despite the reluctance of E.D.F. to require of companies that they use methods involving the use of special lifting equipment. The possibilities of medium and even heavy weight prefabrication are beginning to be taken into account at design level in the studies for the next stage currently being made by E.D.F.

Of course, in order that the medium and heavy prefabrication processes be fully utilised it will be necessary to change the structure of certain constructions, in particular :

- at present, the ribbed joists and slabs used in the floors of the power houses only permit prefabrication of small dimension components. They would need to be replaced by concrete slabs thus enabling prefabrication of heavier units.

- in the machine rooms solid floors would be more easily prefabricated than the present ribbed ones.

- in the Ancillary Equipment building there is no well defined load-bearing structure as all the components are hyperstatic. Because of this, all the units are limited in size and there are not many cost-saving prefabricated components such as concrete partitions and floor slabs on straightforward bearings.

- the present design of the reactor building hardly permits any prefabrication and it is the reactor building which is, as far as the dead-line is concerned, on the critical path. It is the reactor building which determines the start-up of the tranche. It is therefore of utmost necessity to revise the design with a view to using prefabrication methods of construction in order to benefit fully from the substantial time savings which can already be made on the other buildings.

From these examples it is possible, very briefly, to define the most suitable type of structure from the point of view of prefabrication :

- A well defined load-bearing structure formed mainly by continuous shells over the whole height of the building or at least over several levels with large dimension, end-restrained slabs.

- A secondary structure made up of partions or slabs on single bearings, having no structural importance, but which can be easily prefabricated. (uncomplicated joining-up, therefore uncostly).

- New design of the reactor building with a view to using prefabrication methods.
Such changes will require time. They will mean going against the present wide-spread trend of seeking immediate savings, sure-fire savings, simply by cutting down on quantity and rejecting technical solutions which, even if they involves an increase in quantities, permit time to be saved and less labour to be used : savings which, in the longer term, are incomparable with the former (additional benefits, early start-up etc...).

The evolution has begun. Perhaps it is not asking too much to hope that it will continue.

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